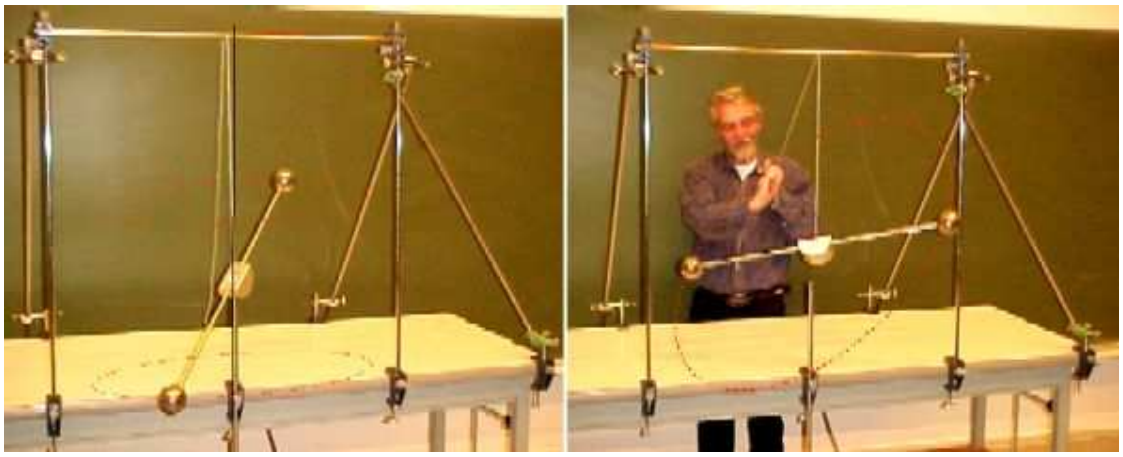
Dumb-bell

Aim: To show that change in direction of angular momentum needs a torque.

Subjects: 1Q40 (Conservation of Angular Momentum)
1Q60 (Rotational Stability)

Diagram:



Equipment:

- Dumbbell pivoted on a support at a non-symmetry axis through the center of mass.
- Frame in order to lift off the dumbbell from the support

Dumb-bell

Presentation: The dumbbell is placed on top of the support. A thread is fixed to the center of mass and thrown over the top of the frame and hold slack, away from the dumbbell. The dumbbell is given a rotation by hand. Make the students observe that the two masses of the rotating dumbbell describe two horizontal circles (Figure1a).

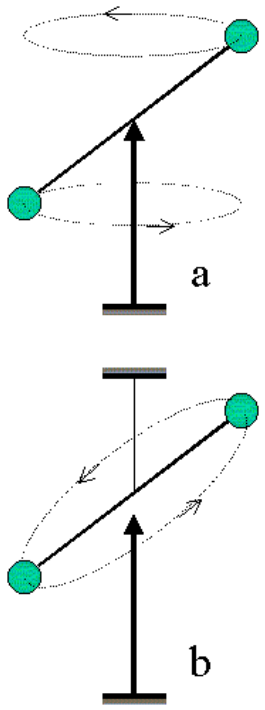


Figure 1

Lift the dumbbell from its support. Almost immediately it can be seen that now the rotation of the dumbbell takes place in one slanting plane (Figure1b).
Before lift-off it can be seen that while the dumbbell rotates, the vertical support shaft oscillates/shakes/wobbles strongly and yet it is a thick and strong steel shaft!

Dumb-bell

Explanation: The dumbbell-shaped object rotates about a non-symmetry axis through the center of mass O. Figure2a shows the angular momentum vector of the rotating dumbbell relative to O at the instant drawn and while the dumbbell rotates the angular momentum vector describes a cone .So the angular momentum changes direction continuously. To do this a torque is needed. The ballbearing support at O gives that torque: A centripetal force F_c is needed to move m around in a circle (see Figure2b). This needs a torque $\vec{F}_c \times \vec{r}$. (Also $\vec{M} = \frac{d\vec{L}}{dt}$ gives this result.)

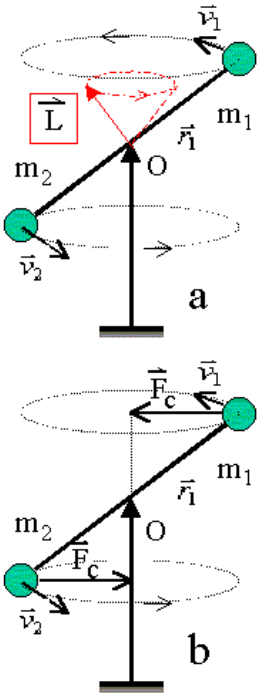


Figure2

This torque also makes the support shaft wobble. The dumbbell needs to rotate in such a way as the direction of $\vec{L}$ dictates at the moment of lift-off.

Remarks:

- The wobbling of the supportshaft can also be described in terms of dynamical unbalance: The angular momentum ($\vec{L}$) and the angular velocity ($\vec{\omega}$) are not parallel.

Sources:

- Alonso, M/Finn, E. J., Fundamentele Natuurkunde, part 1, Mechanica, pag. 215-217
- Borghouts, A.N., Inleiding in de Mechanica, pag. 221-223
- PSSC, College Physics, pag. 352-355 and 366-367
- Roest, R., Inleiding Mechanica, pag. 212-213
- Giancoli, D.G., Physics for scientists and engineers with modern physics, pag. 287